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Fundamental optical nonlinear processes based on  $X_3$  of different materials: organic polymers and liquids, and semiconductors were investigated for size and speed. Ultrafast optical logic devices, switches, and processes based on these nonlinear optical materials were designed, built, and tested. Ten papers were published during 1988 and thirty-one papers were published during the period of the grant (1985-1987).

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FINAL REPORT

AFOSR 88-0039

Subpicosecond Optical Digital Computation Using Conjugate  
Parametric Generators

Senior Researchers: Professors R. R. Alfano, G. Eichman, Yao Li, and  
R. Dorsinville.

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The research program on optical digital computation had two components: (I) a device and application part and (II) a basic fundamental research part. Substantial progress has been achieved in both areas.

I. During 1988, we had the following significant accomplishments in our device and application part of the research:

Optical Computing Device and Application Research

[1] We have extensively studied the device application of an ultrafast optical phase conjugation processor to digital and symbolic logic and arithmetic computation. Despite of using relatively large power, the OPC-based devices offers  $10^6 - 10^9$  times faster processing speed when proper large  $\chi^3$  nonlinear materials, such as organic polymers,



semiconductor-doped glasses are used. This huge gain of computation speed has been observed in our experiments.

[2] We have successfully implemented the following 33 picosecond OPC-based optical computing key elements: a 2 x 2 programmable two-input Boolean logic gate which can be reconfigured to perform all 16 possible logic operations; a 4 x 4 symbolic pattern recognition unit that can identifies 14 different coded symbols needed for optical symbolic substitution operation; a 4 x 4 cross-bar switch array that performs parallel non-blocking interconnect, permutation and has the capability for reconfiguration; a modulo-4 based residue processor that performs optical parallel residue number addition, subtraction and multiplication operations.

[3] We have also studied the possibility of using ultrafast second-order optical nonlinearity for optical computing. In this category, we focused our attention to the use of the noncollinear second harmonic generation for parallel pico- and femtosecond nonabsorptive optical array processing. We have demonstrated both a time-integration-based and a space-integration-based array architectures for array processing. A 17 picosecond 4 x 4 switching array has been experimentally implemented which has been used to perform optical matrix-vector multiplication, dynamic cross-bar interconnect, and optical DMAC-based binary sequence convolution and correlation operations.

[4] We have also developed a new and efficient optical binary encoding scheme which can be referred to as the Venn diagram encoding. With this new scheme, the conventional binary shadow-casting logic can be extended to include multiple input variables. Recently, by combining this new encoding method with a polarization-based optical phase conjugation processor, we have demonstrated a 33 picosecond optical full-adder.

II. Significant accomplishments in the fundamental research program are:

#### Fundamental research

[1] Ultrafast relaxation kinetics of third-order nonlinear susceptibility  $\chi^3$  polysilane polymers was measured using both the picosecond Kerr gate and forward degenerate four-

wave mixing. The third order nonlinear response was on the order of  $2.0 \pm 0.6 \times 10^{-12}$  and faster than 3 ps.

[2] The relaxation time of the transient degenerate four wave mixing grating in 4-butoxycarbonylmethylurethane polydiacetylene in polymethylmethacrylate matrix films has been found to be laser energy fluence dependent. This phenomenon is attributed to a transient reversible light-induced structure change in polydiacetylene films, involving a cooperative effect originating from side-chain intramolecular hydrogen bonding.

[3] We have measured the magnitude and response time of the third order nonlinear coefficient at resonance in a dilute solution of polyacetylene. The relatively large and fast response comparable to results in solid samples, indicates that interchain interactions do not play a significant role in the nonlinear response.

[4] The temperature dependence of transient photoconductivity in stretched trans-polyacetylene films was measured. For the first time, the activation energy for polaron hopping processes was measured (0.048 eV).

[5] Self phase-modulation in  $D_2O$  was used to generate 3 ps pulses by spectral selection of the continuum generated by a 25 ps second harmonic Nd:YAG laser pulse.

[6] The dephasing time of the 1086 cm mode in calcite has been measured as a function of temperature using innovative single shot streak camera technique that measures the phonon dephasing rate in real time. Phonon-phonon interaction models have been proposed and tested to explain the temperature dependence of the experimentally measured dephasing time.

[7] We have measured the magnitude and response time of the third order nonlinear coefficient in a series of polythiophene polymers using picosecond pulses from a mode-locked Nd:YAG laser and four wave mixing techniques. The relative contributions of different nonlinear mechanisms above and below gap were determined by varying the wavelength of the laser pulses and the composition of the polymeric materials. Above gap the nonlinear response was found to be fast ( $< 12$  ps) with one of the largest values of  $\chi^3$

in a polymer ( $> 10^{-9}$  e.s.u.). Below gap, no direct enhancement of the nonlinear response by the induced polaron absorption band was observed.

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